Screening behaviors, demographics, and stage at diagnosis in the publicly funded Ontario Breast Cancer Screening Program.

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Abstract

Purpose. The Ontario Breast Screening Program (OBSP) offers free screening mammograms every two years, to women aged 50-74. Study objectives were to determine demographic characteristics associated with adherence to OBSP and if women screened in OBSP have a lower stage at diagnosis than non-screened eligible women.

Methods. We used the Ontario Cancer Registry (OCR) to identify 51,617 women, aged 50-74, diagnosed with breast cancer between 2010-2017. These women were assigned as screened (N=33,821) or non-screened (N=17,796) in OBSP. We used logistic regression to investigate the demographic characteristics associated with non-screening behaviour. We used multinomial regression to examine the association between screening status and stage at diagnosis.

Results. Among women with breast cancer, those living in rural areas (versus the largest urban areas) had a lower odds ratio (OR) of not being screened (OR: 0.76, 95%CI: 0.72-0.81). Women in low income (versus high income) communities were more likely not to be screened (OR: 1.35, 95%CI: 1.27-1.43). When stratified, the association between income and screening status only held in urban areas. Non-screened women were more likely to be diagnosed stage II (OR: 1.76, 95%CI: 1.68-1.85), III (OR: 2.73, 95%CI: 2.56-2.92), or IV (OR: 6.93, 95%CI: 6.24-7.69) disease compared to stage I and were less likely to be diagnosed with ductal carcinoma in-situ (DCIS) (OR: 0.90, 95%CI: 0.85-0.96).

Conclusions. This study suggests that targeting OBSP recruitment efforts to lower income urban communities could increase screening rates. OBSP adherent women were more likely to be diagnosed at earlier stages, supporting the value of this initiative and those like it.

Introduction

Breast cancer is the most commonly diagnosed malignancy in women worldwide, with one in eight women in Canada expected to develop the disease in their lifetime [1]. In the province of Ontario Canada, the Ontario Breast Screening Program (OBSP) provides breast cancer screening with mammography every two years to eligible women in the population (ages 50–74 years). Along with these age criteria, to be eligible, women must have no new breast cancer symptoms, personal history of breast cancer, breast-implants, or history of mastectomy [2]. Annual screening is available for women who have a family history of breast or ovarian cancer, extremely dense breasts, or a history of high-risk lesions [2, 3]. In the year 2018 approximately 77% of all women eligible for breast cancer screening, within and outside of the OBSP, received a screening mammogram within the previous 30 months [3]. While it is good that nearly two-thirds of women in Ontario had received at least one mammogram during this interval, there is still a substantial proportion of screening-eligible women who may be under-screened or not screened at all. This is concerning as there is evidence that breast cancer screening leads to the diagnosis of early-stage disease, [4, 5] which in turn is associated with lower breast cancer mortality [6].

Those who undergo breast cancer screening are known to differ from those that do not, based on some key demographic characteristics. For example, it has been shown that individuals living in a rural community [7] or having low-income socio-economic status [8] are less likely to participate in breast cancer screening in the United States and the Netherlands respectively. Understanding the characteristics of individuals who do not get screened is essential to inform policies seeking to increase participation and adherence in breast screening programs. This will ensure equitable access to and sharing of the benefits of such programs.

Accordingly, this study had two main objectives. The first was to identifying characteristics associated with participation in the OBSP and the second is to determine if OBSP screening is indeed associated with a lower stage at diagnosis.

Methods

Study Population

The retrospective cohort under investigation was identified through the Ontario Cancer Registry (OCR) and includes records for all women ages 50–74 years in Ontario diagnosed with a first primary breast cancer (invasive or ductal carcinoma in situ [DCIS]) between 2010 and 2017 (N = 56,306) (Fig. 1). Information on breast cancer screening was obtained from OBSP records and included 145,274 screening records spanning from 2006–2017. These records represented singular screening events from 43,953 unique patients (Fig. 1).

For women with a second primary breast cancer between 2010–2017 (n = 3,955), only information on their first breast cancer diagnosis in that time-period was included. An individual woman in the sample could have multiple screening events through routine participation in the OBSP. Symptomatic (diagnostic) breast cancer screening events (n = 8,890), any screening event for women with breast implants (because screening recommendations in the OBSP differ for women with breast implants, n = 170) and screening events from individuals with missing information on age (n = 5,033 screening events) were excluded. Women in the High Risk OBSP, or those who were eligible for the High Risk OBSP (n = 620) were excluded, because these individuals follow different screening guidelines [3].

Screening Behaviour

Adherent screeners were defined as those who had one OBSP mammogram at least once every three years for those eligible for biennial screening or once every two years for those on annual recall screening. We provided women with a grace period of approximately one year for both annual and biannual screening to allow for variability due to scheduling. Conversely, women who had been diagnosed with breast cancer but had no record of screening within OBSP, were defined as non-screening individuals. Women who had at least one OBSP screen, but not every two to three years (i.e., non-adherent screeners) were excluded from the analysis (n = 333). After the application of all exclusion criterion the final cohort size of individual women was 51,617 (85.4%) (Fig. 1).

Cancer Stage and Tumor Characteristics

Data based on the TNM stage guidelines was used to define cancer stage for this analysis. This classification guideline uses tumor size (T), number of surrounding lymph nodes with cancer (N), and cancer metastasis (M) to determine the stage of cancer at diagnosis. Within this dataset, stage zero cancers included any non-staged forms of breast cancer such as Paget's disease or Phyllodes tumours [9, 10]. DCIS was classified in its own category. Missing data was classified as unknown cancer stage (N = 1,901, 3.7%). Data for both estrogen (ER) and progesterone (PR) receptor status, and human epidermal growth factor receptor 2 (HER2) status was also obtained from the OCR. The outcomes for these three hormone receptors were classified as positive, negative, or unknown (includes borderline status).

Patient Characteristics

Data on an individual's community size, urban or rural setting and income was obtained from Ontario Health (Cancer Care Ontario). Statistics Canada's definition of census metropolitan areas (CMA) using Canadian census data was used [11]. CMA is defined as urban areas of differing population size from under 100,000 people, 100,000-499,999, 500,000–1,499,999, or over 1,500,000. Individuals who lived outside of CMA's were defined as living in a rural community [11]. All instances where community size was missing were coded as 'Unknown' (N = 782, 1.5%).

Before tax neighbourhood income quintile data was categorized as a three-category variable combining the three middle income quintiles (middle, lower-middle, upper-middle) into a single middle income level, while the lowest and the highest income quintiles were maintained as is [12]. Any missing income data was classified as unknown in the model (N = 782, 1.5%).

Statistical Analyses

Standardized differences (SD) were used to compare patient characteristics (e.g., residential community size, neighbourhood income, age, and presence of a prior non-breast cancer (yes/no)), and tumour characteristics such as cancer stage, ER, PR and HER2 receptor status between non-screeners and adherent screeners. A standardized difference greater than or equal to 0.1 was used to represent a meaningful difference between groups [13].

Multivariable adjusted binomial logistic regression was used to estimate odds ratios (OR) and 95% confidence intervals (CI) for the association between age, neighbourhood income, residential community size, and prior non-breast cancer with screening behaviour (non-screener versus adherent screener) in a mutually adjusted model. A second model was run exploring the potential interaction between community size and income quintile using a product term. This led to models being stratified by community size. Multinomial logistic regression (generalized logit) was used to examine the association between screening behaviour (adherent screener versus non-screener) and cancer stage at diagnosis (stage I-IV, DCIS, and non-staged cancer). Age, prior non-breast cancer, and residential community size were all treated as confounders for this analysis.

All tests were two-sided, and a p-value of less than 0.05 was considered statistically significant. Data cleaning and standardized differences were performed in R, and all model creation and diagnostics were performed in SAS Studio Version 9.4.

Results

The median age at breast cancer diagnosis was 62 years, with screen adherent women being slightly older than those who were not screened (SD = 0.21). Most of the cohort (38.7%) resided in a metropolitan area with a population of more than 1,500,000 people, while 11.9% of the cohort lived in a rural setting (Table 1). Most women also fell within the middle-income category (59.1%), with no difference in screening behaviours observed(SDs < 0.1) (Table 1).

Table 1
Demographic variables and breast cancer characteristics stratified by screening behaviour for women diagnosed with a first breast cancer in Ontario between 2010–2017.

	Overall	Adherent Screening	Non-Screening	Standardized Differences:[f]
	(N = 51617)	(N = 33821)	(N = 17796)	Adherent vs. Non-Screening
Age[a]				
Mean (SD)	61.8 (7.07)	62.3 (6.78)	60.8 (7.50)	**0.21**
Median	62	63	61	
Neighbourhood Income				
Highest	11119 (21.5%)	7476 (22.1%)	3643 (20.5%)	0.04
Middle[b]	30485 (59.1%)	20200 (59.7%)	10285 (57.8%)	0.04
Lowest	9231 (17.9%)	5670 (16.8%)	3561 (20.0%)	0.08
Unknown	782 (1.5%)	475 (1.4%)	307 (1.7%)	0.03
Urban/Rural Community Size[c]				
Urban Population < 100,000	4603 (8.9%)	3063 (9.1%)	1540 (8.7%)	0.01
Urban Population 100,000–499,999	11567 (22.4%)	8366 (24.7%)	3201 (18.0%)	**0.17**
Urban Population 500,000–1,499,999	8525 (16.5%)	5348 (15.8%)	3177 (17.9%)	0.06
Urban Population > 1,500,000	19979 (38.7%)	12350 (36.5%)	7629 (42.9%)	**0.12**
Rural Area	6161 (11.9%)	4219 (12.5%)	1942 (10.9%)	0.05
Unknown	782 (1.5%)	475 (1.4%)	307 (1.7%)	0.03
Prior non-breast Cancer				
No	47640 (92.3%)	31150 (92.1%)	16490 (92.7%)	0.02[g]
Yes	3977 (7.7%)	2671 (7.9%)	1306 (7.3%)	
Cancer Stage				
I	21080 (40.8%)	15584 (46.1%)	5496 (30.9%)	**0.32**
II	14711 (28.5%)	8970 (26.5%)	5741 (32.3%)	**0.13**
III	4828 (9.4%)	2403 (7.1%)	2425 (13.6%)	**0.22**
IV	1892 (3.7%)	558 (1.6%)	1334 (7.5%)	**0.28**
DCIS	7009 (13.6%)	5253 (15.5%)	1756 (9.9%)	**0.17**
Non-Staged[d]	196 (0.4%)	134 (0.4%)	62 (0.3%)	0.01
Unknown	1901 (3.7%)	919 (2.7%)	982 (5.5%)	**0.14**
Estrogen Receptor				
Negative	6263 (12.1%)	3837 (11.3%)	2426 (13.6%)	0.07
Positive	34302 (66.5%)	22604 (66.8%)	11698 (65.7%)	0.02
Unknown[e]	11052 (21.4%)	7380 (21.8%)	3672 (20.6%)	0.03
Progesterone Receptor				
Negative	10396 (20.1%)	6492 (19.2%)	3904 (21.9%)	0.07
Positive	30100 (58.3%)	19899 (58.8%)	10201 (57.3%)	0.03
Unknown[e]	11121 (21.5%)	7430 (22.0%)	3691 (20.7%)	0.03
HER2 Status				
Negative	25992 (50.4%)	17838 (52.7%)	8154 (45.8%)	**0.14**

	Overall	Adherent Screening	Non-Screening	Standardized Differences:[f]
	(N = 51617)	(N = 33821)	(N = 17796)	Adherent vs. Non-Screening
Positive	4598 (8.9%)	2869 (8.5%)	1729 (9.7%)	0.04
Unknown[e]	21027 (40.7%)	13114 (38.8%)	7913 (44.5%)	**0.12**

Abbreviations: HER2 - Human Epidermal Growth Factor Receptor 2, DCIS – Ductal Carcinoma In-Situ

[a]Age for this cohort was restricted to participants between the age of 50 to 74 to reflect those eligible for the Ontario Breast Cancer Screening Program average risk eligibility group.

[b]The middle income classification represents a combination of all individuals who fell within the middle three quintiles of the neighbourhood income distribution named lower-middle, middle, upper-middle income.

[c]Community size is differentiated by population size. Urban area is defined as being part of a population center, while rural areas are areas surrounding urban areas without a population center.

[d]Non-staged breast cancer represents invasive stage zero forms of breast cancer such as Paget's disease, Phyllodes tumors, and angiosarcoma of the breast.

[e]Unknown receptor status of breast cancer tumours represent both cases that had no data on receptor status and tumors in which results were borderline and unable to be classified.

[f]Differences above 0.1 (in bold font) represent meaningfully differences in distributions for a variable level. Comparisons are made of compliant screeners versus non-screening individuals.

[g]Since prior cancer is a binary variable, only one standardized difference was generated to show comparisons between the levels, since no 'dummy' variables needed to be coded.

Overall, stage I cancers were the most (40.8%, N = 21,080) and stage IV, the least (3.7%, n = 1,892) common stage at diagnosis in the cohort (Table 1). Of all the women diagnosed with breast cancer between 2010 and 2017, 65% were classified as being adherent screeners. In unadjusted analyses, the relative fraction of stage I cancers was larger amongst adherent screeners versus non-screeners (SD = 0.32). Correspondingly, non-screeners had a higher proportion of stage II (SD = 0.13), III (SD = 0.22), and IV (SD = 0.28) cancers. DCIS was more frequent in adherent screeners compared to non-screening individuals (SD = 0.17).

The majority of cancers with available information on receptor status (ER: 78.6%, PR: 78.4%, 59.3% HER2) were ER-positive (84.6%) and HER2-negative (85.0%). A larger proportion of screen-adherent women were HER2 negative (SD = 0.14) and a smaller proportion had unknown HER2 receptor status (SD = 0.12), but there was a similar proportion of women with HER2 positive cancers regardless of compliance (SD < 0.1) (Table 1).

Patient characteristics and screening behaviours

The odds of being a non-screener decreased with every 5-year increase in age (OR = 0.86, 95% CI 0.85,0.87) (Table 2). Compared to those living in an urban area of over 1,500,000 people, the odds of being a non-screener were significantly lower for those living in smaller urban areas, including communities with a population under 100,000 (OR = 0.84, 95% CI 0.79, 0.90), between 100,000-499,999 people (OR = 0.63, 95% CI 0.60, 0.66), and for those living in a rural area (OR = 0.76, 95% CI 0.72, 0.81). An association between neighborhood income and screening status was also observed. Specifically, the odds of being a non-screener compared to an adherent screener were significantly higher for those in the lowest- and middle-income categories compared to the highest (OR = 1.35, 95% CI 1.27, 1.43; OR = 1.08, 95% CI 1.03, 1.13 respectively).

Table 2
Binomial logistic regression measuring the association of age, community Size, neighborhood income, and prior non-breast cancer with the screening behaviours of Ontario women diagnosed with breast cancer from 2010–2017 (n = 51,617)

Adjusted Risk Factor[a]		**Non-Screening vs. Adherent Screening[b]**		
		OR	95% CI	
Age[c]		**0.86**	**(0.85,**	**0.87)**
Urban vs. Rural Area Code (Compared to Urban Area 1,500,000 + People)[d]	Urban 500,000–1,499,999	0.98	(0.93,	1.03)
	Urban 100,000-499,999	**0.63**	**(0.60,**	**0.66)**
	Urban < 100,000	**0.84**	**(0.79,**	**0.90)**
	Rural	**0.76**	**(0.72,**	**0.81)**
	Unknown	**1.19**	**(1.03,**	**1.39)**
Neighborhood Income[e]	Lowest vs. Highest	**1.35**	**(1.27,**	**1.43)**
	Middle vs. Highest	**1.08**	**(1.03,**	**1.13)**
	Middle vs. Lowest	**0.80**	**(0.76,**	**0.84)**
Prior Non-Breast Cancer[f]	Yes vs. No	0.98	(0.92,	1.05)

Abbreviations: OR – Odds Ratio, CI – confidence interval

[a]In this model there is no focal exposure. The relationships of covariates with screening behaviours are explored.

[b]Screening behaviour is considered the outcome of interest for this analysis. Adherent screening behaviour is considered the reference level, and the relationship of non-screening vs. adherent screening is shown.

[c]Age is a continuous variable increasing in units of 5.

[d]Urban and rural community size is a categorical variable. Rural areas are defined as surrounding urban areas that have no population center of their own. Urban areas with over 1,500,000 people act as the reference level for this variable.

[e]Neighborhood income is a categorical variable with three levels. Highest represents the wealthiest neighbourhood income quintile. Middle represents the combined middle three income quintiles. Lowest represents the poorest neighbourhood income quintile.

[f]Prior non-breast cancer is a binary variable, with 'Yes' acting as the reference level.

A significant interaction between community population size and income was observed (p = 0.008). In a model stratified by community population size, it was found that the effect of income on screening behaviour differed by community population size (Table 3). Specifically, lower income was associated with an increased odds of being a non-screener across all urban areas, but was not associated with screening adherence among those living a rural setting. For urban areas over 1,500,000 people, the odds of being a non-screener were highest for women in the lowest versus highest income category (OR = 1.45 95% CI 1.32, 1.58), and remained elevated for the middle versus the highest income category (OR = 1.12 95% CI 1.05,1.21). This pattern was consistent across urban areas of different population sizes (Table 3).

Table 3
Binomial logistic regression measuring the association of age, neighborhood income, and prior non-breast cancer with the screening behaviours of Ontario women diagnosed with breast cancer from 2010–2017, stratified by population size (n = 51,617)

Variables[a]		**Non-Screening vs. Adherent Screening**[b]									
		Urban vs. Rural Population Size[c]									
		Urban Area Over 1,500,000		Urban Area 500,00–1,499,999		Urban Area 100,000–499,999		Urban Area Under 100,000		Rural Area	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age[d]		**0.86**	**(0.84, 0.88)**	**0.88**	**(0.85, 0.90)**	**0.85**	**(0.83, 0.88)**	**0.86**	**(0.83, 0.90)**	**0.87**	**(0.84, 0.90)**
Neighborhood Income[e]	Lowest vs. Highest	**1.45**	**(1.32, 1.58)**	**1.39**	**(1.21, 1.61)**	**1.32**	**(1.16, 1.50)**	**1.35**	**(1.11, 1.65)**	1.03	(0.86, 1.23)
	Middle vs. Highest	**1.12**	**(1.05, 1.21)**	0.97	(0.87, 1.08)	1.07	(0.96, 1.19)	1.14	(0.97, 1.34)	1.02	(0.88, 1.16)
	Middle vs. Lowest	**0.78**	**(0.72, 0.84)**	**0.70**	**(0.62, 0.79)**	**0.81**	**(0.73, 0.90)**	**0.84**	**(0.72, 0.99)**	0.99	(0.86, 1.14)
Prior Non-Breast Cancer[f]	Yes vs. No	1.04	(0.93, 1.16)	0.93	(0.78, 1.11)	0.90	(0.77, 1.06)	1.05	(0.84, 1.30)	0.97	(0.79, 1.18)

Abbreviations: OR – Odds Ratio, CI - Confidence Interval

[a]In this model there is no focal exposure. The relationships of all covariates with screening behaviours are explored.

[b]Screening behaviour is considered the outcome of interest for this analysis. Adherent screening behaviour is considered the reference level, and the relationship of adherent screening vs non-screening is shown.

[c]Urban and rural population size is a categorical variable. Rural areas are defined as surrounding urban areas that have no population center of their own. Urban areas with over 1,500,000 people act as the reference level for this variable.

[d]Age is a continuous variable increasing in units of 5.

[e]Neighborhood income is a categorical variable with three levels. Highest represents the wealthiest neighbourhood income quintile. Middle represents the combined middle three income quintiles. Lowest represents the poorest neighbourhood income quintile.

[f]Prior non-breast cancer is a binary variable, with 'Yes' acting as the reference level.

Table 4. Multinomial logistic regression measuring the association of breast cancer screening behaviour, age, neighbourhood population, and presence of a prior-non breast cancer with cancer stage in Ontario women diagnosed with breast cancer from 2010–2017 (n = 51,617)

Adjusted Risk Factor[a]		Cancer Stage[b]											
		In-situ		Non-Staged[c]		II		III		IV		Unknown	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Screening Behaviour[d]	Non-Screening vs. Adherent Screening	**0.90**	**(0.85, 0.96)**	1.26	(0.93, 1.71)	**1.76**	**(1.68, 1.85)**	**2.73**	**(2.56, 2.92)**	**6.93**	**(6.24, 7.69)**	**2.87**	**(2.61, 3.17)**
Age[e]		0.98	(0.97, 0.98)	1.00	(0.98, 1.02)	0.98	(0.98, 0.98)	0.97	(0.97, 0.98)	1.00	(0.99, 1.01)	0.99	(0.99, 1.00)
Urban vs. Rural Community Size (Urban Area 1,500,000 + People)[f]	Urban 500,000–1,499,999	0.98	(0.91, 1.06)	0.92	(0.62, 1.36)	1.09	(1.02, 1.16)	1.22	(1.12, 1.34)	0.94	(0.81, 1.09)	0.50	(0.43, 0.59)
	Urban 100,000-499,999	0.82	(0.77, 0.88)	0.57	(0.38, 0.85)	0.98	(0.93, 1.04)	1.00	(0.92, 1.09)	1.28	(1.13, 1.45)	0.52	(0.45, 0.59)
	Urban < 100,000	0.78	(0.70, 0.87)	0.86	(0.52, 1.42)	1.05	(0.97, 1.13)	0.99	(0.88, 1.12)	1.08	(0.90, 1.29)	0.65	(0.54, 0.78)
	Rural	0.83	(0.76, 0.91)	0.50	(0.29, 0.87)	1.01	(0.94, 1.08)	1.03	(0.92, 1.14)	1.06	(0.90, 1.24)	0.60	(0.51, 0.71)
	Unknown	0.66	(0.52, 0.86)	1.38	(0.56, 3.43)	0.93	(0.78, 1.12)	0.87	(0.66, 1.16)	0.86	(0.56, 1.32)	2.62	(2.07, 3.31)
Prior Non-Breast Cancer[g]	Yes vs. No	1.03	(0.93, 1.14)	1.15	(0.71, 1.88)	0.93	(0.85, 1.00)	0.87	(0.77, 0.99)	0.76	(0.63, 0.93)	1.47	(1.26, 1.71)

Abbreviations: OR – Odds Ratio, 95% CI – 95% Wald Confidence Intervals

[a]Model adjusted for age, community size, and presence of a prior non-breast cancer

[b]Cancer stage is a categorical variable representing the outcome of interest for this model. Stage one cancer is used as the reference level for cancer stage.

[c]Non-staged cancer represents invasive non-staged breast cancers such as Paget's Disease, Phyllodes tumors, and angiosarcoma of the breast.

[d]Screening behaviour is a categorical variable representing the focal exposure of interest in this model. Compliant screening is the reference level for this variable. Non-screening is the other screening behaviour defined in this dataset. Data was linked from OBSP. All those who did not have screening records in OBSP were classified as non-screening individuals for this cohort.

[e]Age is a continuous variable increasing in units of 1.

[f]Urban and rural community size is a categorical variable. Rural areas are defined as surrounding urban areas that have no population center of their own. Urban areas with over 1,500,000 people act as the reference level for this variable.

[g]Prior non-breast cancer is a binary variable, with 'Yes' acting as the reference level.

Screening behaviour and tumour stage at diagnosis

Non-screeners had 10% lower odds of being diagnosed with DCIS compared to adherent screeners (OR = 0.90, 95% CI 0.85, 0.96) (Table 4). Conversely, compared to stage I disease, the odds of being diagnosed with stage II (OR = 1.76, 95% CI 1.68, 1.85), III (OR = 2.73, 95% CI 2.56, 2.92), or IV (OR = 6.93, 95% CI 6.24, 7.69) breast cancer were higher for non-screeners compared to adherent screeners and increased with increasing stage.

Discussion

Overall, among women diagnosed with breast cancer in Ontario between 2010 and 2017, those that were screened according to OBSP guidelines were less likely to be diagnosed with later stage disease. In particular, non-screeners had an almost 7-fold higher odds of being diagnosed with stage IV disease. However, as expected, these women were less likely to be diagnosed with DCIS (OR = 0.90, 95% CI 0.85, 0.96). In addition to this, we found that Ontario women residing in urban areas with lower neighborhood income had higher odds of being a non-screener.

Among women with breast cancer who were eligible to be screened in the OBSP (i.e., women ages 50–74 years), most individuals were adherent screeners (n = 33,821, 65.5%), while a minority did not screen at all, or were exclusively screened outside of OBSP (n = 17,796, 34.5%). This is consistent with previous research [14]. Notably, very few women (N = 333) engaged in non-adherent screening, (i.e., had a screening mammogram that did not follow OBSP guidelines). This suggests that individuals who get screened, tend to participate fully in the program, following OBSP guidelines. Focus on efforts to increase screening initiation in women living in larger urban areas with lower neighborhood income will increase

screening rates among screen-eligible women, at least amongst those diagnosed with breast-cancer. Further, increasing screening rates is likely to reduce the number of late-stage cancers diagnosed, improving cancer outcomes.

Prior work from the OBSP has shown that about 83% of OBSP women who initiated screening returned for a subsequent screen, and that this proportion consistently increased from 1992–2001 [14]. However, more recent trends suggest that screening retention has actually decreased in Ontario from 83% in 2012 to 77% in 2018 [3]. In particular, it has been shown that the odds of returning for a second screen are highest for those living in rural compared to urban areas [15]. However, when compared to the broader literature, the impact of rural versus urban living on screening behaviour is mixed. Some studies based in the United States have found that access to breast screening is more available in urban centers. This is reflected in the higher screening rates for women living in urban versus rural areas [7, 16, 17]. Other studies, in Australia and Croatia (both with publicly funded screening), have shown similar screening rates in women living in rural and urban settings [18, 19]. The literature suggests that access to screening services does tend to be lower for women living in rural areas [18, 20]. On the contrary, in our study, we found that women living in rural areas were less likely to be non-screeners. This suggests that having an organized, province-wide, publicly funded, screening program mitigates some of the rural-urban disparities in screening rates observed in other jurisdictions.

Data has also shown that those in the lowest neighborhood income category tend to have higher odds of not being screened compared to those in the middle- or highest- neighborhood income categories [8, 21, 22]. Consistent with the evidence, in our study, lower- and middle-income individuals were more like to be non-screeners when compared to those in the highest income quintile. This is despite the fact that OBSP screening is publicly available, without the need for referral from primary care, and has no associated cost for the patient [23]. Prior research of low-income African American women in the United States has shown that mistrust of the medical system, inadequate education about screening, and the presence of barriers (e.g., lack of childcare and transportation) may limit the ability of some individuals to attend screening [24, 25]. Work is needed to determine if similar barriers to screening exist in Ontario, preventing low- and middle-income women from attaining the same degree of screening as their higher-income counterparts.

Notably, while we did observe differences in screening rates with income, this effect was limited to women living in an urban setting, with no observed differences in screening behavior based on income for individuals living in a rural area. Conversely, in urban areas, differences in screening behaviour for individuals with low, middle, and high income were observed. Here, the odds of being a non-screener were highest for individuals in the lowest income category (OR = 1.45 95% CI 1.32, 1.58 compared to high income individuals). This suggests that screening behaviour differences associated with the effects of income may only exist for those living in urban environments and not in rural areas. Similar research into the interaction of income and community size on breast screening has been performed in low-income countries [26]. Here, it was found that both urban and rural residing low-income women had significantly lower odds of mammography attendance, however the effect size for rural residing women was smaller in comparison to urban residing women [26]. Further research into breast cancer screening behaviour should focus on what specific barriers to screening exist for low-income, urban residing women that do not exist for low income rural residing women.

The effectiveness of breast cancer screening programs in reducing the incidence of advanced stage breast cancer has been shown in multiple studies [4, 5, 27–29]. Consistent with these findings, the results from this analysis show a clear gradient of an increasing odds of stage II (OR = 1.76, 95% CI 1.68, 1.85), III (OR = 2.74, 95% CI 2.56, 2.92), and IV (OR = 6.93, 95% CI 6.24, 7.69) cancers in non-screeners. These results suggest that regular breast cancer screening, within OBSP guidelines, is effective in reducing later stage cancer diagnoses. While performance measures of the OBSP have been analyzed [14, 30, 31], to our knowledge, this is the first analysis to look at differences in cancer stage for breast cancer patients who did or did not participate in the OBSP during this time-period. These results highlight the effectiveness of breast screening in Ontario in achieving the goal of reducing the incidence of later stage disease.

Rates of diagnosis of DCIS are known to be higher in a screening population [32]. Accordingly, in this study we found non-screeners to be less likely to be diagnosed with DCIS compared to adherent screeners (OR = 0.90, 95% CI 0.85, 0.96). It was expected that more cases of DCIS would be found in adherent screeners (15.5%) compared to non-screeners (9.9%).

This study has numerous strengths, including the use of a large population-based cohort of women diagnosed with breast cancer identified through a provincial cancer registry. This allowed for robust comparisons between adherent screeners and non-screeners. The OCR also includes detailed information on tumour characteristics (e.g., stage, ER-status) that can be linked to demographic characteristics of the women within this population.

Limitations of this study include a lack of information on personal income levels, race/ethnicity and immigration status of women diagnosed with breast cancer in Ontario. The absence of these key demographic variables limited our ability to examine their impact on breast cancer screening behaviours, and therefore limited the conclusions we could draw from this current analysis. Further, the study population only included women who were diagnosed with breast cancer, so when looking at demographic characteristics that associate with breast cancer screening behaviour, these associations may only exist amongst women diagnosed with breast cancer. However, screening behaviours were captured through OBSP records and only included screens conducted prior to diagnosis, and all women known to be at high risk of breast cancer (i.e., screened as part of the High Risk OBSP) were excluded from the analysis. Because the coverage of the OCR and the OBSP is province-wide, it is expected that the screening behaviours in this study population should reflect those of the broader population. Further evidence of this is seen in the similar screening rates (65.5%) in the study population, as compared to the general population of Ontario in 2018 (66.0%) [3]. Another limitation is that eligible women who exclusively screened outside OBSP would have been classified as non-screeners in this sample since only OBSP screening data was available.

However, it would be expected that screening adherent women misclassified as non-screening would move the associations seen with cancer stage at diagnosis towards the null hypothesis. The fact that these results still show a strong association of non-screening and higher cancer stage at diagnosis suggests that this population of non-OBSP screeners was not sufficient to move the association towards the null hypothesis.

This research highlights important differences between women who are screened according to the guidelines of a province-wide, publicly funded screening program, and those who do not get screened at all. Women who followed these screening guidelines were less likely to have been diagnosed with late-stage breast cancer. Furthermore, being younger, urban residing, or having a lower neighbourhood income were all associated with a greater likelihood of not undergoing any breast cancer screening. Notably, few women were non-adherent screeners, suggesting that once women initiate screening, most tend to follow the guidelines set out by OBSP. This highlights the need for focused interventions aimed to increase screening initiation urban residing, low-income women, to increase screening rates and ensure that more breast cancers are detected before they progress to more advanced, and serious stages.

Declarations

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Author Contributions: GMA and JDB conceived of the design of the study, oversaw analysis, and drafting the manuscript. NG conducted the data analysis and drafted the manuscript. RAGC, contributed to study design, data analysis and drafting of manuscript. All authors have read and approved the final manuscript.

Availability of data and materials: The data that support the findings of this study are available from Ontario Health (Cancer Care Ontario), a prescribed entity under section 45 of the Personal Health Information Protection Act. Data sharing regulations prevent these data from being made available publicly due to the personal health information in the datasets. Data are however available from the authors upon reasonable request and with permission of Ontario Health (Cancer Care Ontario).

Ethics approval and consent to participate: This study was approved by the Research Ethics Board at the University of Toronto. Data was provided by Ontario Health (Cancer Care Ontario), a prescribed entity under Ontario's privacy legislation, which is authorized to collect and use personal health information for the purpose of research. Therefore, participant consent was not required.

Consent for Publication: Not applicable.

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Figures

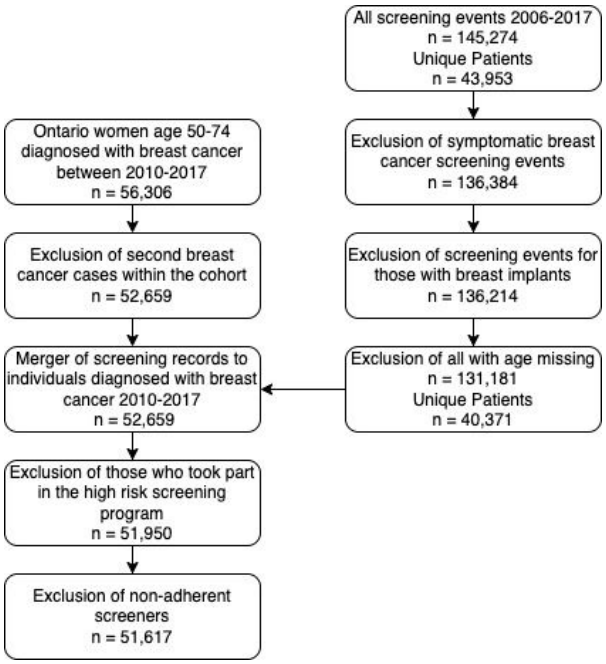

Figure 1

Flowchart of cohort size after each exclusion step for Ontario Health data on women diagnosed with breast cancer, and its linkage to data on OBSP screening events.